Project ID: EEMS011

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Multimodal Travel Behavior Modeling in Urban Areas using BEAM

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2017 VTO Annual Merit Review

June 8, 2017

Argonne NATIONAL LABORATORY

INL Idaho National Laboratory

BERKELEY LAB

OAK RIDGE National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Overview

Timeline

- Start date: 10/2016
- End date: 09/2019
- Percent complete: 17%

Budget

- Total funding: $1.68M
  –DOE share: 100%
- FY 2016: Zero
- FY 2017: $0.56M

Barriers

- Limited understanding of system-impacts of mobility mega-trends
- Scalable modeling of future transportation system difficult
- Models need appropriate representation of behavior

Partners

- Project Lead: LBNL
- Partners: LBNL, UC Berkeley, Conveyal, NREL, ANL, INL, ORNL

Objectives & Relevance

- Transportation systems becoming more dynamic, connected, and complex
- Travelers are faced with more modal options and situational awareness than ever before
- This project aims to endogenize traveler behavior in BEAM – a fully multimodal and scalable urban simulation tool – to understand the impact of behavior on regional energy outcomes

Milestones

Date	Pillar	Milestone	Status
June 2017	Mobility Decision Science	Enable full range of multi-modal travel decision making in Agent-based transportation system models	On schedule
September 2017	Mobility Decision Science	Early simulation model results for energy/GHG estimates for multiple MDS scenarios for SF Bay and Chicago	On schedule
September 2017	Multimodal	Develop a transit vehicle energy module for use in BEAM	On schedule

Approach: Systems Modeling

- Enhance existing modeling capabilities to enable large-scale, agent-based simulations of multimodal urban transportation systems
- Design an extensible simulation framework that can readily accommodate new mobility modes and new insights into or models of traveler behavior
- Validate the model against existing data sources
- Conduct normative analyses of mobility mega-trends

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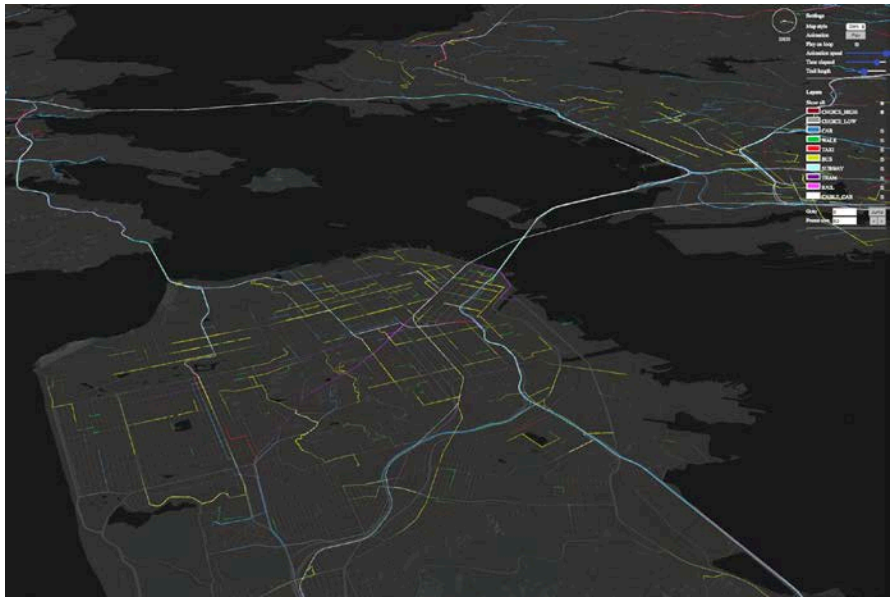
Technical Accomplishments Summary

- BEAM Overall Design Work
- Preliminary Implementation
- AgentSim
  - –Actor System
  - –Agents as Finite State Machines
  - –Behavior and Operations Modeling
- Router: Open Trip Planner
- Coupled model to vizualizer

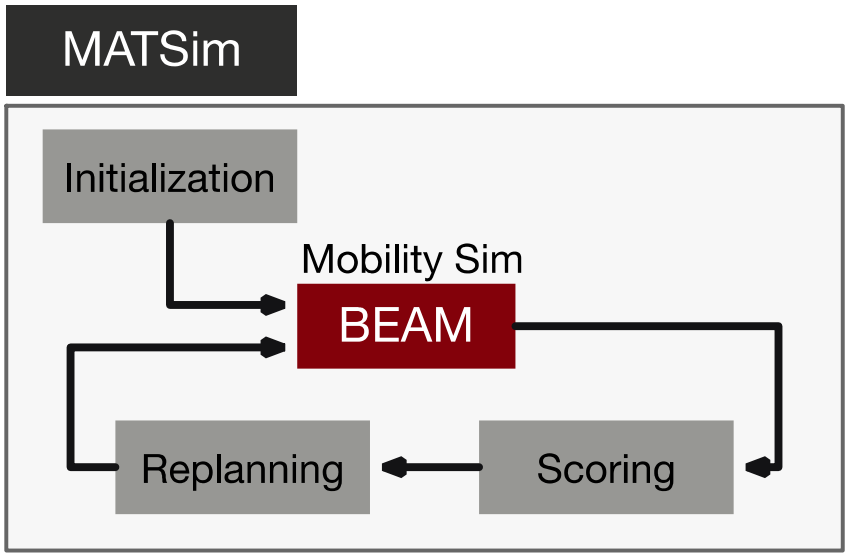


BEAM Extends MATSim

- Extends MATSim Framework
- MATSim (Multi-Agent Transportation Simulation) is an agent-based dynamic traffic assignment model
- Highly extensible including:
  - Multimodal
  - Alt. Fuels
  - TNCs
  - Dynamic Pricing
  - Etc.
- Co-evolutionary algorithm to maximize personal utility (through scoring and replanning

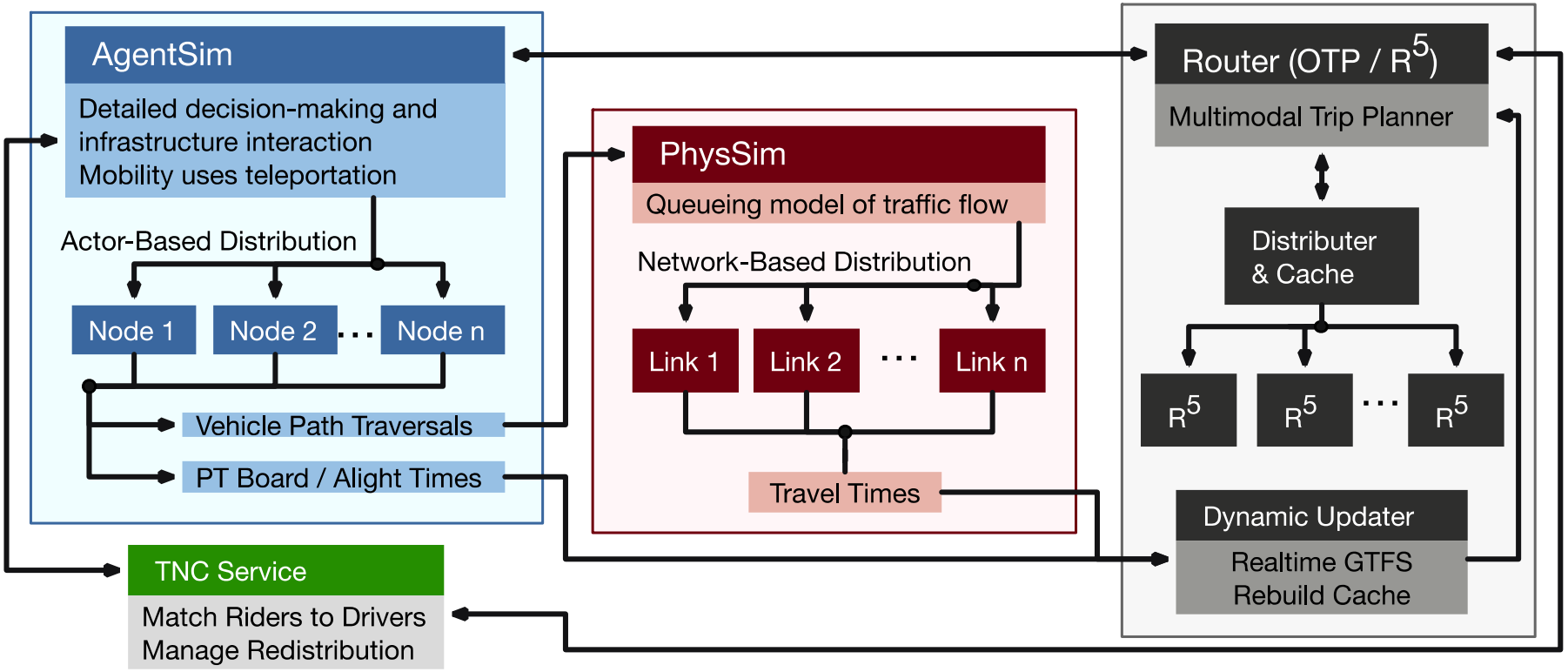
MATSim Multi-Agent Transport Simulation

BEAM



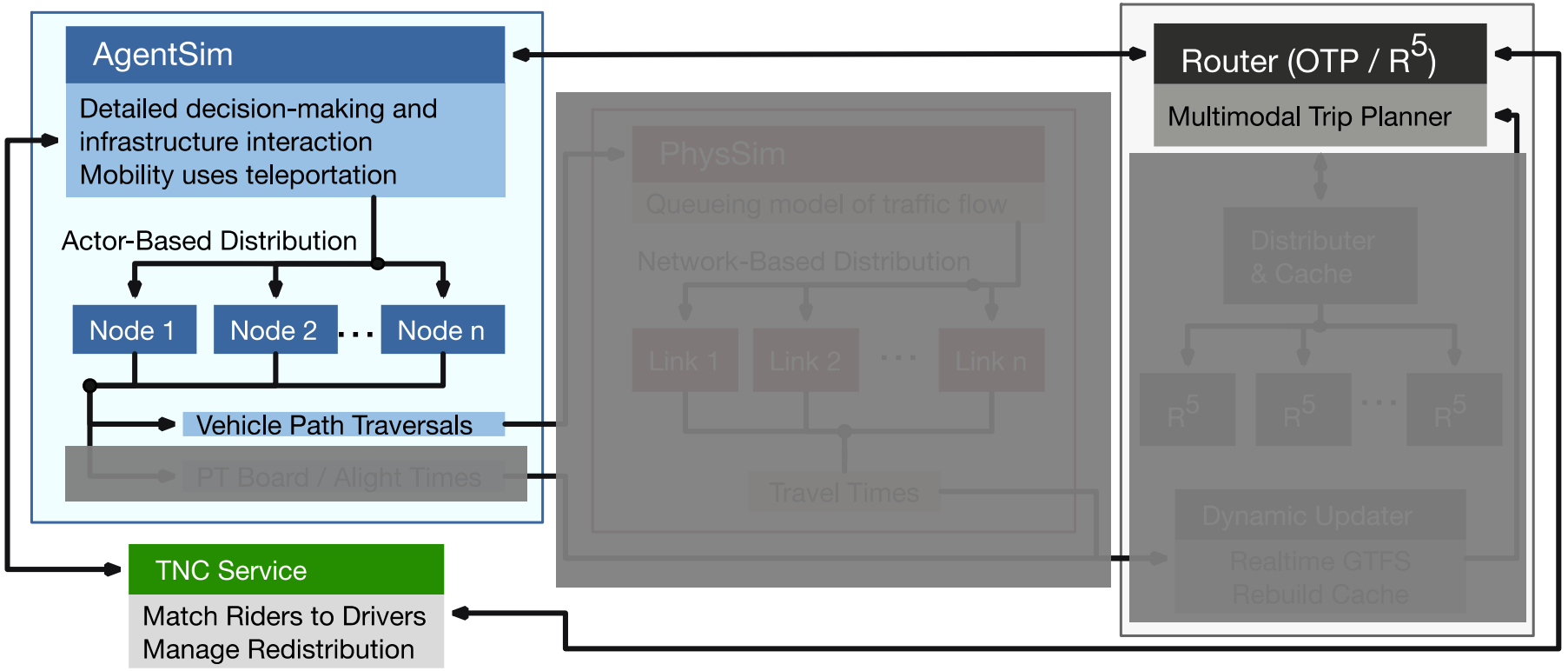
BEAM Architecture

- Core components decoupled: AgentSim, PhysSim, Router
- Each component designed for flexibility & distribution
- AgentSim written in Scala leverages advanced programming patterns

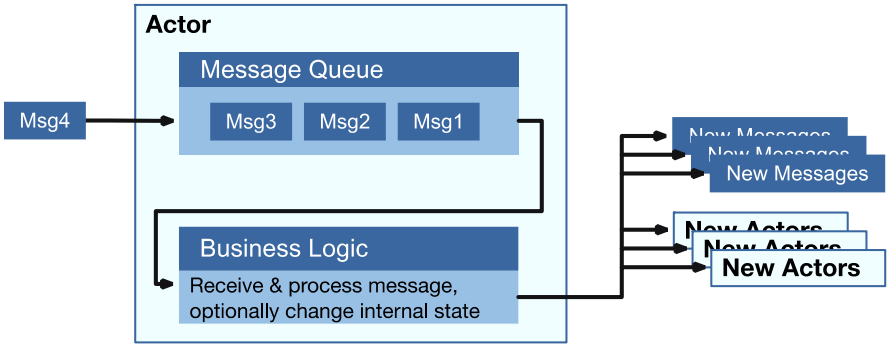


Preliminary Impementation

1. Agents request multimodal routes
2. Router returns menu of options
3. TNC Service adds taxi as option if available
4. Agents choose and execute route

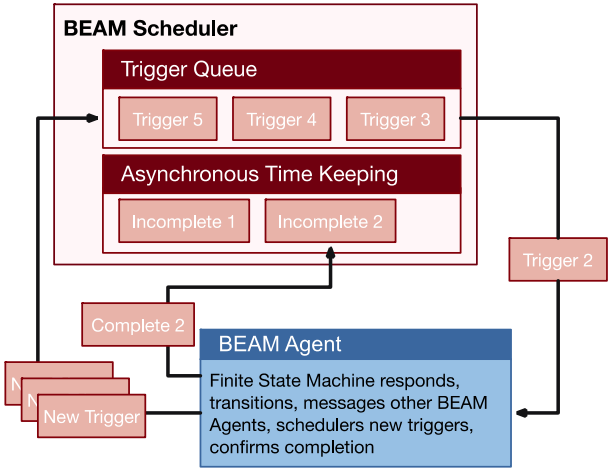


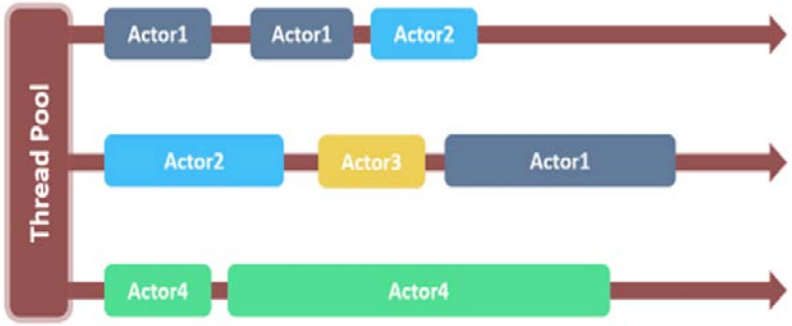
AgentSim: Actor System



- Adopted the actor model of computation: message-passing, asynchronous, approach to concurrent programming

- BEAM Scheduler relaxes strict chronology in model execution, enabling massively distributed agent computations



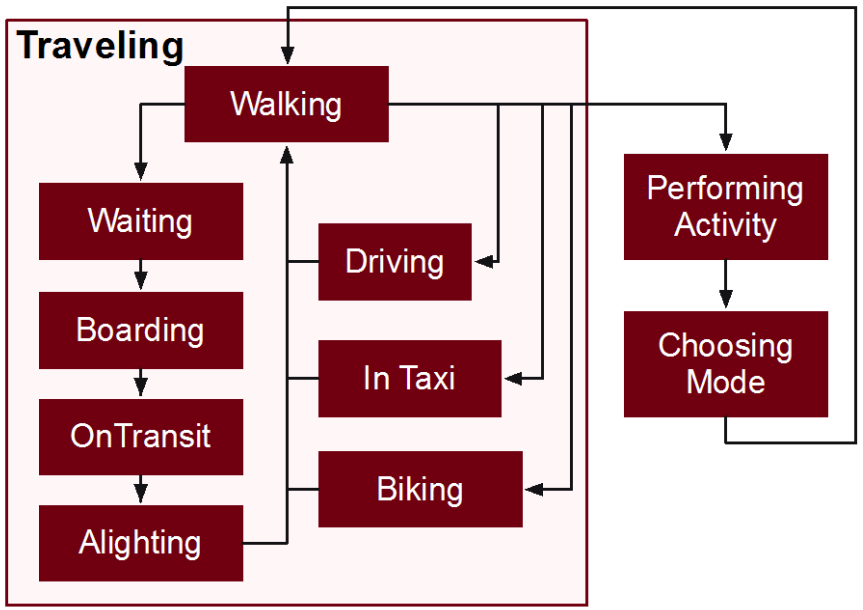


- Akka actor system manages multi-plexing, threading, and cluster deployment

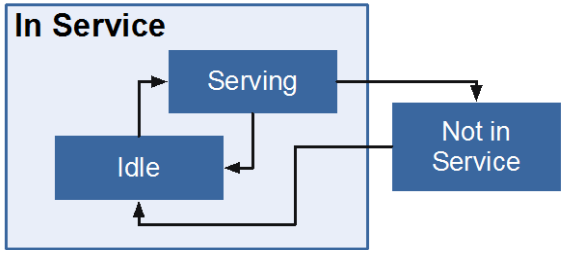
AgentSim: Finite State Machines

- Beam agents (persons, vehicles, infrastructure, etc.) are finite state machines
- Allowing abstracted management of entities and simplified integration of new agent types

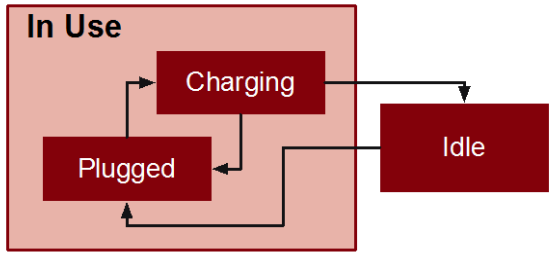
Person Agents



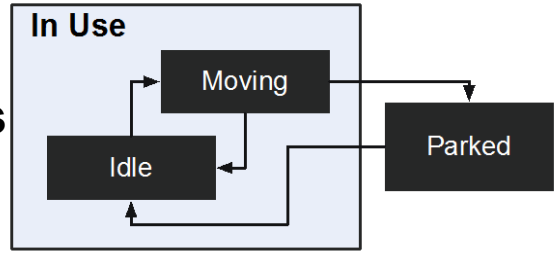
Taxi Agents



Charger Agents



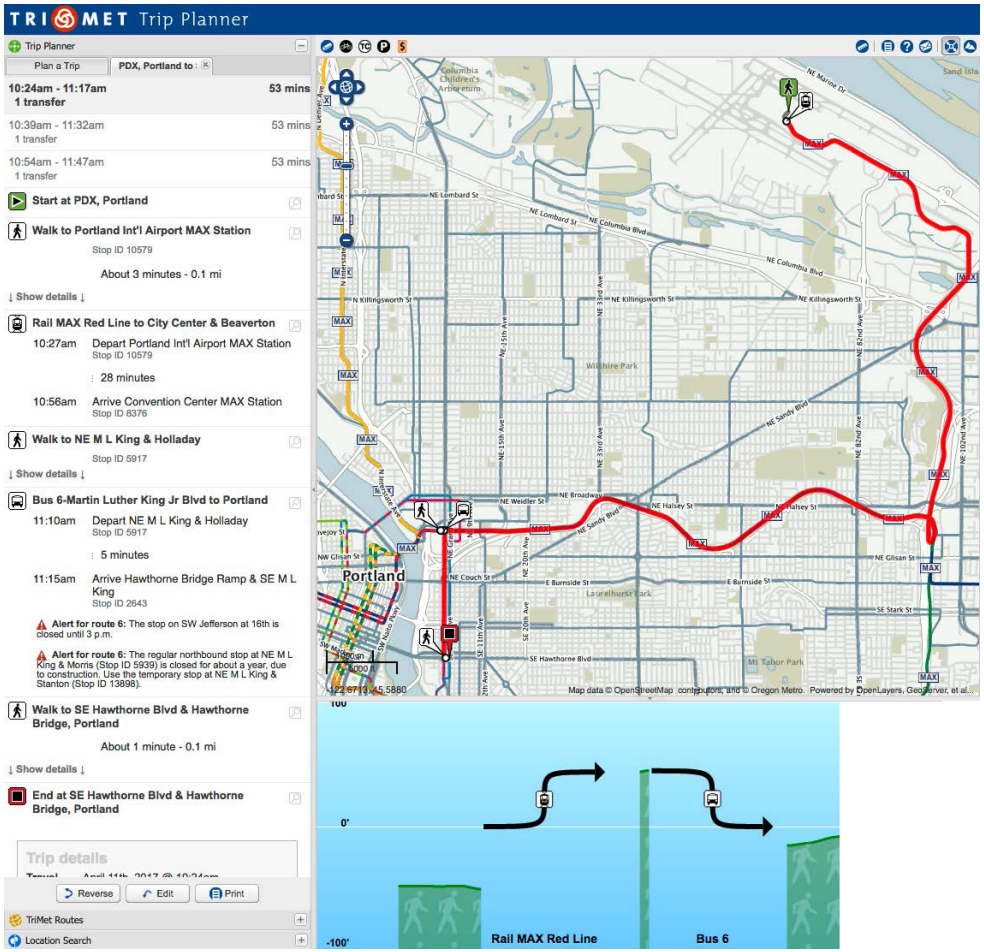
Vehicle Agents



AgentSim: Behavioral & Operations Modeling

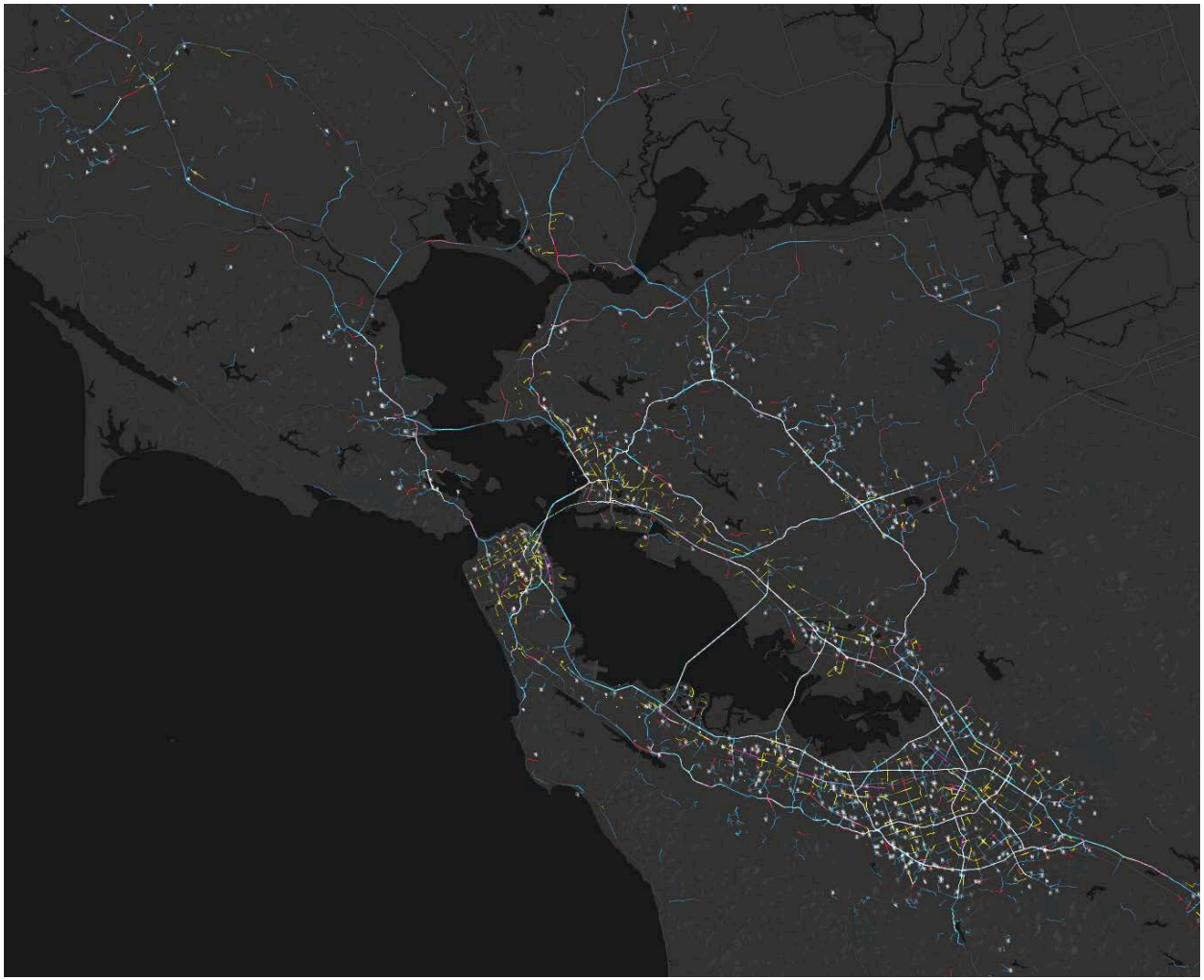
- Initial focus on short-run to medium-run behavior
- Design is focused on enabling BEAM to be a test bed for alternative behavioral and operational models:
  - –Mode choice
  - –Route choice
  - –TNC empty vehicle re-distribution
  - –Shared dispatch
- All behavior and operations use real-time system information and trip planner guidance

Router: Open Trip Planner



- Multimodal routing is well studied and great open source tools exist
- BEAM leverages existing rather than recreates
- Open Trip Planner already integrated
- Agents base mode choice on the routes returned by OTP
- Highly configurable and capable of adapting to realtime GTFS events

Visualization



Response to FY16 Reviewers

This project is new in FY17

Collaborations

Smart Cities Research Center

- Machine learning with cell tower data

conveyal

- Authors of Open Trip Planner & R5
- Assisting with integration of router into BEAM

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- ANL: Collaboration on common reduced form energy consumption modeling
- INL: Choice modeling for PEV charging behavior
- NREL & ORNL: Vehicle adoption forecasts

Remaining Challenges

- BEAM focus is on enabling flexible modeling of traveler behavior, but team will rely on SMART collaborators to supply plausible models to test
- Also focus on enabling a test bed for operations research in mobility services design, but team will rely on collaborators to provide scalable algorithms
- More software design and engineering to accomplish before we can begin scientifically rigorous demonstrations of predictive capability

FY17 Remaining Work

- Complete model enhancements:
  - Implement multiple mode choice models
  - Implement multiple TNC dispatch algorithms
  - Implement vehicles and vehicle assignment algorithm
  - Endogenize energy consumption models in vehicles
  - Complete integration of existing network traffic simulation module from MATSim
  - Integrate advanced and scalable routing capability
  - Additional vizualization features (point processes, aggregated results viewer)

FY18-FY19 Future Work

- Complete model enhancements
- Conduct preliminary calibration of behavioral models (to be updated as more data and relevant studies are published)
- Conduct normative studies, e.g.:
  - Impact of large scale TNC deployment impact on energy
  - Test efficacy of policies for energy efficient mode shifting
  - Policies on empty vehicle movements
  - Explore dependency between electrification, infrastructure, and mobility mega-trends

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Summary

- Emerging transportation system is complex and evaluating the impact of emerging technologies in isolation can be problematic
- Agent-based models enable whole systems approach to assess impacts of mega-trends
- BEAM reenvisions the architecture necessary to achieve scalable and flexible mobility simulations for urban regions
- Much progress in ~4 months of work by leveraging existing open source tools

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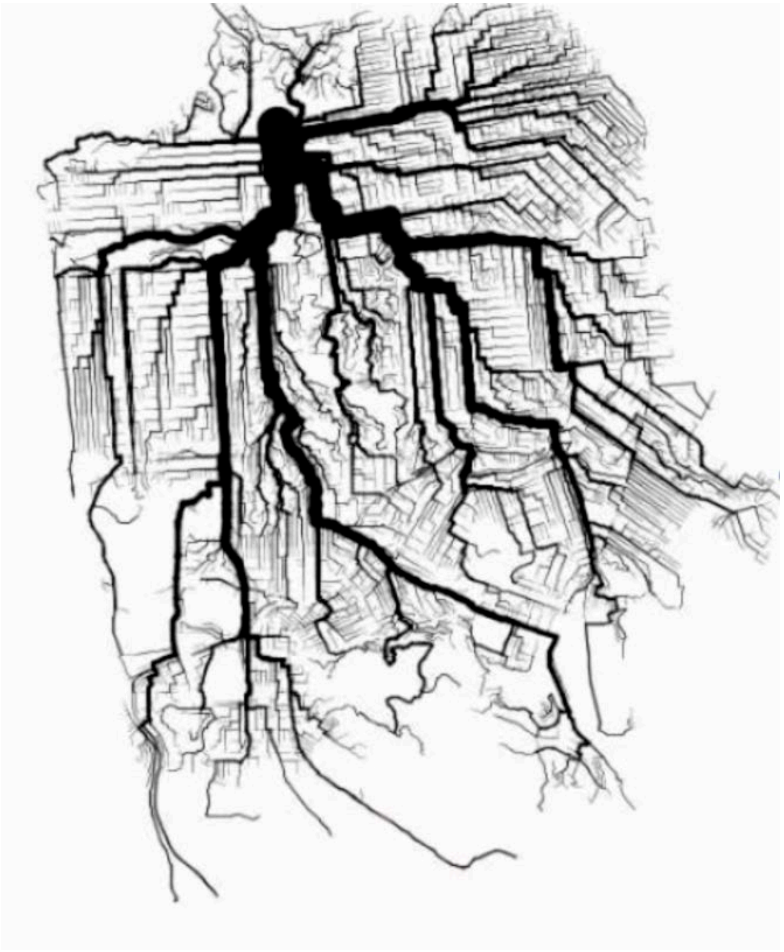
QUESTIONS?

Technical Back-Up Slides

Future Work – Routing with R^5



- Any shortest path computation (left) allowed to explore full network forms a shortest path tree SPT
- By distributing the SPT computation and caching results (right), routing requests become fast
- R^5 is designed for parallel execution and cloud deployment